

# MICROFABRICATED VAN DE GRAAF

## BACKGROUND OF THE INVENTION:

### Field of the Invention:

The present invention relates generally to power supplies for applications and devices that require small, low-cost, high-voltage power supplies. These power supplies can be used, for example, in high-density and ultra-high-density data storage devices.

### Description of the Related Art:

FIG. 1 illustrates a portion of a Van De Graaf apparatus according to the related art. A Van De Graaf apparatus is typically manufactured on a macroscopic scale and is often used to raise the hair of students during high school science demonstrations as the students touch the apparatus with their hands.

The portion of the apparatus illustrated in FIG. 1 has a charged species source 10 that is connected to an electrical ground 20. In close proximity to the edge or tip of the charged species source 10 is a belt 30 that is wrapped around a first roller 40 and a second roller 50. The belt 30 travels in a closed path around the rollers 40, 50 as the rollers 40, 50 turn or spin about their fixed axes 45, 55.

The first roller 40 is either positively or negatively charged and the second roller 50 either remains uncharged or is oppositely charged relative to the first roller 40. Away from the charged species source 10, but also proximate to the belt 30, is positioned a charged species drain 60. The charged species drain 60 is electrically connected to a device 70 such as a power supply or capacitor. During operation, the Van De Graaf apparatus supplies a current to the device 70.

The charged species source 10 generally is made from a metal or other conductive material. The charged species source 10 generally takes the shape of a pin or a comb. However, other geometries are sometimes used.

The belt 30 is typically made of rubber. The first roller 40 typically is made from a material other than rubber. The second roller 50 is typically made of a material that is neither the material used to make the belt 30 nor the material used to make the first roller 40. However, under certain circumstances, the second roller 50 and the belt 30 are made from the same material.

The charged species drain 60 can be made from a metal or other conducting material. The charged species drain 60 is often in the shape of a pin or a comb, although other geometries are sometimes used. The device 70 to which the charged species drain

1 60 is electrically connected can be any type of apparatus that would benefit from a high  
2 potential current being supplied to it.

3 When operating the Van De Graaf apparatus, the first roller 40 typically  
4 undergoes a charging process. The first roller 40 can be either positively or negatively  
5 charged, depending on the type of charged species that are used to supply current to the  
6 device 70. For example, if electrons are used, the first roller 40 is positively charged.

7 In order to charge the first roller 40, charged species may be supplied to the first  
8 roller 40 from an outside source. Alternatively, the first roller 40 can be tribocharged.

9 Tribocharging involves "frictional charging" between two contacting surfaces that  
10 are made from different materials. Since different materials attract electrons with  
11 different amounts of force, tribocharging operates on the principle that, when two  
12 different materials rub against each other, the electrons in the surface atoms of one  
13 material will be more strongly attracted to the other material and will effectively "tear  
14 off" of one material in order to attach themselves to the other. If the materials continue to  
15 rub against each other over time, one material will become more and more negatively  
16 charged while the other material will become more and more positively charged as  
17 surface atom electrons continue to move from one material to the other.

18 In FIG. 1, the surfaces of the first roller 40 and of the belt 30 move relative to each  
19 other when the first roller 40 turns and moves the belt 30. Also, because the belt 30 and  
20 first roller 40 are made from different materials, charged species from the surface of the  
21 belt 30 are transferred to the surface of the first roller 40. Therefore, over time the first  
22 roller 40 becomes charged. The belt also gets charged, but because it is larger, the  
23 charged species are more diffuse.

24 When it is desirable for the second roller 50 to be oppositely charged relative to  
25 the first roller 40, the material from which the second roller 50 is made can be chosen  
26 such that, as the surface of the belt 30 moves relative to the second roller 50,  
27 tribocharging occurs that is opposite in polarity to the tribocharging that occurs between  
28 the first roller 40 and the belt 30. In other words, in FIG. 1, the belt 30 can tribocharge  
29 the first roller 40 with one type of charged specie and can charge the second roller 50  
30 with an oppositely charged specie.

31 When, on the other hand, it is desirable that an uncharged second roller 50 be  
32 used, the belt 30 and the second roller 50 can be manufactured from the same material,  
33 thereby preventing tribocharging. Also, even if different materials are used to make the

1 belt 30 and second roller 50, the charged species that build up in the second roller 50 can  
2 be quickly removed by an external electrical connection.

3 Once the desired charging has occurred in each of the rollers 40, 50, the charged  
4 species source 10 is "turned on" and charged species begin to flow towards the tip of the  
5 charged species source 10 closest to the belt 30. The charged species at the tip of the  
6 charged species source 10 then get attracted by the charged first roller 40 and travel  
7 towards it. However, the charged species do not travel through the belt 30 and therefore  
8 effectively become attached to the belt 30.

9 Once the charged species are attached to the belt 30, the moving belt 30 transports  
10 the charged species from a position near the first roller 40 to a position near the  
11 oppositely charged or uncharged second roller 50. Once the charged species are near the  
12 second roller 50, they either experience no electrostatic forces between themselves and  
13 the second roller 50 or experience repulsive electrostatic forces that repel the charged  
14 species away from the second roller 50.

15 The unattracted or repelled charged species then approach the charged species  
16 drain 60. When the species get close enough to the drain 60, they move off of the surface  
17 of the belt 30, through the drain 60, and to the device 70 where they supply a current at a  
18 high electrostatic potential.

19 The related art device illustrated in FIG. 1 has the disadvantage that it can only be  
20 used on a macroscopic scale. Further, a significant amount of energy is required to move  
21 the belt 30 by using the first roller 40 and second roller 50.

## 22 **BRIEF SUMMARY OF THE INVENTION:**

23 A method of manufacturing an electronic-charge-transferring device that includes  
24 providing a charged species source and a charge species drain, and manufacturing a  
25 moveable component for transferring charge to the charged species drain, a first  
26 protrusion proximate to the moveable component, and a second protrusion proximate to  
27 the moveable component, wherein the moveable component is positioned in close  
28 proximity to the charged species source, and wherein at least one of the moveable  
29 component, the first protrusion and the second protrusion is micro-manufactured.

30 A method of transferring electric charge that includes providing a first charged  
31 species source and a first charged species drain, micro-manufacturing at least one of a  
32 first moveable component, a first protrusion, and a second protrusion, wherein the  
33 moveable component is positioned proximate to the first charged species source and the  
34 first charged species drain, and wherein the first protrusion and the second protrusion

1 each contact the first moveable component, and moving the first moveable component  
2 relative to the first charged species source and the first charged species drain.

3 A van de graaf device that includes a moveable component, a charged species  
4 source proximate to the moveable component, a charged species drain proximate to the  
5 moveable component, a first protrusion contacting the moveable component, and a  
6 second protrusion contacting the moveable component, wherein at least one of the  
7 moveable component, the first protrusion and the second protrusion is micro-machined.

# 8 **BRIEF DESCRIPTION OF THE DRAWINGS:**

9 The invention will be described by way of example, in the description of  
10 exemplary embodiments, with particular reference to the accompanying drawings in  
11 which:

12 FIG. 1 illustrates several components of a macroscopic Van de Graaf apparatus  
13 according to the related art;

14 FIG. 2 illustrates one embodiment of a microscopic or nanoscopic Van de Graaf  
15 apparatus according to the present invention;

16 FIG. 3 illustrates a flowchart of a method of manufacturing an electronic-charge-  
17 transferring device according to certain embodiments of the present invention; and

18 FIG. 4 illustrates a flowchart of a method of transferring electric charge according  
19 to certain embodiments of the present invention.

# 20 **DETAILED DESCRIPTION OF THE INVENTION:**

21 FIG. 2 illustrates an embodiment of a micro-fabricated Van De Graaf apparatus  
22 according to the present invention. The apparatus illustrated in FIG. 2 includes a charged  
23 species source 10 connected to a electronic ground 20.

24 The apparatus of FIG. 2 also includes a charged species drain 60 electrically  
25 connected to a device 70. Both the charged species source 10 and drain 60 are positioned  
26 either proximate to, or in contact with, a plate 80. The plate 80 can be any component  
27 that has the ability to move relative to the source 10 and drain 60. For example, the plate  
28 80 may be able to translate relative to the source 10 and drain 60 or may be able to rotate  
29 about a rotation axis 85. In those embodiments where the plate 80 translates, a  
30 micromover (not illustrated), such as the one disclosed in U.S. Patent No. 5,557,596 to  
31 Gibson, et al., may be used. The plate 80, source 10, and drain 60 can all be  
32 manufactured according to standard micro-machining techniques or can be manufactured  
33 on a nanometer scale.

1 Also included in the apparatus illustrated in FIG. 2 is a first protrusion 90 and a  
2 second protrusion 100, each positioned in contact with the plate 80. The plate 80 can  
3 move relative to the protrusions 90, 100 either by translating or rotating.

4 A micro-fabricated van de graaf apparatus can be used in a variety of applications.  
5 For example, such an apparatus can be used to supply current to a micro-fabricated device  
6 such as, but not limited to, a power supply or data storage device like the ultra-high  
7 density storage device disclosed in U.S. Patent No. 5,557,596 to Gibson, et al.

8 The source 10 and the drain 60 can each be of any geometry including, but not  
9 limited to, a pin or a comb. The source 10 and drain 60 can be made from or include a  
10 conductive material such as, but not limited to, a metal or metal alloy.

11 The plate 80 can be made from or include a material that is capable of being  
12 micro-manufactured or nano-manufactured. According to certain embodiments, the  
13 material is one that is capable of moving relative to the protrusions 90, 100 without  
14 experiencing significant wear. In other words, in certain embodiments, the plate 80 is  
15 able to move relative to the protrusions 90, 100 a number of times, and in one or more  
16 directions, without failing.

17 The plate 80 can be manufactured to include a non-conductive material. For  
18 example, the translating plate 80 can include a rubber-like material or a polymer material  
19 such as, but not limited to, a photoresist layer that has been hardened to resist wear.

20 The protrusions 90, 100 can be micro-manufactured and can be chosen to have  
21 dimensions on a micro-meter scale or smaller. The first protrusion 90 can include a  
22 material that is different from a material included in either the plate 80 or the second  
23 protrusion 100. The second protrusion 100 can include a material that is also different  
24 from a material in the first protrusion 90 and the plate 80.

25 During operation, the source 10 is "turned on" and charged species flow to the tip  
26 of the source 10 closest to the plate 80. The plate 80 (or another moveable component)  
27 can be made to oscillate along a direction parallel to the surfaces of the protrusions 90,  
28 100 that are in contact with the plate 80. For example, in the Cartesian coordinate system  
29 illustrated on the left of FIG. 2, the plate 80 can translate across the xy-plane or may  
30 rotate around the rotation axis 85.

31 Also during operation, the first protrusion 90 can be charged opposite to the  
32 charge of the species that flow from the source 10. Charging of the first protrusion 90 can  
33 either be done by an external device or by tribocharging with the plate 80 as the plate 80  
34 moves relative to the first protrusion 90.

1 The second protrusion 100 can be of the same polarity as the charged species that  
2 are emanating from the source 10. On the other hand, the second protrusion 100 can  
3 remain uncharged. When the second protrusion 100 remains uncharged, charge can either  
4 be removed from the second protrusion 100 by an external device or the second  
5 protrusion 100 can be chosen such that it contains the same materials as the plate 80 and  
6 therefore does not tribocharge.

7 Once the electron source 10 begins to have charge species flowing from its tip, the  
8 charged species can be attracted to the first protrusion 90 because of the opposite polarity  
9 of the first protrusion 90. However, the charged species do not travel through the plate 80  
10 and instead collect on the surface of the plate 80. When the plate 80 moves relative to the  
11 first protrusion 90 and toward the drain 60, the charged species on the surface of the plate  
12 80 are also moved towards the drain 60.

13 Once the charged species are near the drain 60, the second protrusion 100 either  
14 provides a repulsive electrostatic force or provides no electrostatic force. Either way, the  
15 charged species can be attracted to the drain 60 and migrate through the drain 60 and  
16 towards the device 70, thereby supplying the device 70 with a current.

17 The source 10 and drain 60 are generally positioned in close proximity to the plate  
18 80. As discussed above, the plate 80 can be rotated around the fixed rotation axis 85.  
19 Under a rotating plate 80 configuration, the charged species on the surface of the plate 80  
20 travel through a semicircular path instead of a linear one. Nonetheless, a current is still  
21 generated and supplied to the device 70.

22 According to other embodiments of the present invention, multiple sources 10 and  
23 drains 60 can be used in conjunction with one or more plates 80, first protrusions 90 and  
24 second protrusions 100. When multiple micro-fabricated Van De Graaf apparatuses are  
25 micro-manufactured and operated at the same time, each plate 80 can be oscillated  
26 between the sources 10 and drains 60 at periodic rates that are out of phase with each  
27 other.

28 In other words, when one translating plate 80 is at the beginning of an oscillation  
29 between a source 10 and a drain 60, another translating plate 80 can be half-way through  
30 its oscillation, and yet a third translating plate 80 can be at the end of its oscillation  
31 towards a drain 60, and in the process of moving back towards a source 10. When  
32 simultaneous translating plates 80 are in operation and oscillating out of phase with each  
33 other, a more steady current can be generated to the device 70. When a rotating plate 80

1 is used, multiple sources 10, drains 60 and first and second protrusions 90, 100 can still  
2 be used, but the net effect would be an increasing current to the device 70.

3 When a translating plate 80 is used, the length of the translating plate 80 often  
4 defines the distance over which the plate 80 oscillates. Since a portion of the plate  
5 generally remains over the source 10 in order to pick up charge species that are then  
6 translated to the electron drain 60, once the source 10 is near the edge of the translating  
7 plate 80, the oscillation reverses itself and the translating plate 80 is generally reset to its  
8 initial position. Then, the entire process is resumed as the plate 80 once again picks up  
9 and translates charged species between the source 10 and the drain 60.

10 During the resetting, because charged species are no longer transported from the  
11 source 10 to the drain 60, current generally does not flow to the device 70. However, the  
12 embodiments where a rotating plate 80 spins about a rotation axis can provide continuous  
13 current to the device 70 because no resetting is necessary. Further, the staggered  
14 oscillations of the plates 80 discussed above can also provide constant current.

15 FIG. 3 illustrates a flowchart of a method of manufacturing an electronic-charge-  
16 transferring device according to certain embodiments of the present invention. This  
17 method may start with step 200, which specifies that a charged species source 10 and a  
18 charged species drain 60 be provided. According to certain embodiments, the source 10  
19 and drain 60 can be micro-manufactured, though no particular size limitations are made  
20 on the source 10 and drain 60. Step 200 may also provide the source 10 and drain 60 to  
21 be in contact with a moveable component, such as, but not limited to, the plate 80  
22 illustrated in FIG. 2.

23 Step 210 specifies the manufacture of the moveable component for transferring  
24 charge to the charged species drain 60, a first protrusion 90 proximate to the moveable  
25 component, and a second protrusion 100 proximate to the moveable component, wherein  
26 the moveable component is positioned in close proximity to the charged species source  
27 10, and wherein at least one of the moveable component, the first protrusion 90 and the  
28 second protrusion 100 is micro-manufactured. Step 210 may, according to certain  
29 embodiments, specify including a first material in the first protrusion 90 and a second  
30 material, different from the first material, in the second protrusion 100. Further, step 210  
31 may specify including a third material, different from the first material and the second  
32 material, in the moveable component.

1 Step 220 specifies that the first protrusion 90 and the second protrusion 100 be  
2 positioned in contact with the moveable component. In such embodiment, there is  
3 friction between the protrusions 90, 100 and the moveable component.

4 Step 230 specifies that a device 70 be electrically connected to the charged species  
5 drain 60. Any device 70 is within the scope of the present invention, so long as the  
6 device 70 could benefit from the current of charged species flowing through the drain 60.

7 FIG. 4 illustrates a flowchart of a method of transferring electric charge according  
8 to certain embodiments of the present invention. According to FIG. 4, step 300 specifies  
9 that a first charged species source 10 and a first charged species drain 60 be provided.  
10 The source 10 and drain 60 may be micro-manufactured, although no particular size  
11 restrictions are placed on either the source 10 or the drain 60.

12 Step 310 specifies micro-manufacture at least one of a first moveable component,  
13 a first protrusion 90, and a second protrusion 100, wherein the moveable component is  
14 positioned proximate to the first charged species source 10 and the first charged species  
15 drain 60, and wherein the first protrusion 90 and the second protrusion 100 each contact  
16 the first moveable component. Also, although step 310 specifies micro-manufacturing,  
17 nanometer-scaled manufacturing and larger-scaled manufacturing are also within the  
18 scope of certain embodiments of the present invention.

19 Step 320 specifies moving the first moveable component relative to the first  
20 charged species source 10 and the first charged species drain 60. According to certain  
21 embodiments of the present invention, the moving step 320 includes translating the first  
22 moveable component relative to the first charged species source 10. According to other  
23 embodiments, the first moveable component may be rotated about a rotation axis 85.

24 Step 330 specifies tribocharging the first protrusion 90 and the second protrusion  
25 100. Then, according to step 340, the first charged species drain 60 may be used to  
26 supply an electric current to a device 70. The device 70 may be any item that would  
27 benefit from being supplied from an electrical current.

28 Step 350 then specifies providing a second moveable component, a second  
29 charged species source, and a second charged species drain, each positioned proximate to  
30 the second moveable component, and a third protrusion and a fourth protrusion, each  
31 positioned proximate the second moveable component, wherein the first charged species  
32 drain 60 and the second charged species drain are each electrically connected to a device  
33 70. Step 360 then specifies moving the second moveable component out of phase with  
34 the first moveable component. In such a configuration, when a translating first moveable



1 component is moving away from the first charged species drain 60, the second moveable  
2 component may move toward the second charged species drain, thereby providing the  
3 device 70 with a more steady electric current.

4 The foregoing detailed description has been given for understanding exemplary  
5 implementations of the invention only and no unnecessary limitations should be  
6 understood therefrom as modifications will be obvious to those skilled in the art without  
7 departing from the scope of the appended claims and their equivalents.

0995765 1.12901